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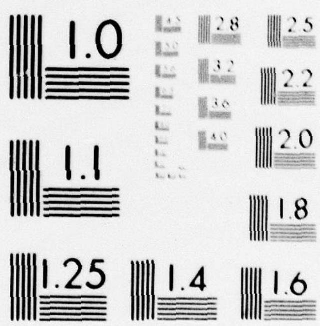
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(6) Experiments in Electrocutaneous Information Transfer*

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FOR THE CHIEF:

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Since the second World War, the information processing load on weapon system operators has, in some cases, increased to the limits of the channel capacities of the operator's visual and auditory senses. Future systems may require the operator to process still more information. However, it may be feasible to increase the operator's total channel capacity by providing another sensory channel in addition to the commonly used visual and auditory channels. The possibility of using a cutaneous communications channel has been suggested by a number of previous investigators including, to name a few, Geldard, Hawkes, Slivinski, Sumby and Loeb.

This paper presents the results of several separate studies, conducted by Applied Psychological Services under contract with the U. S. Army Electronics Research and Development Laboratories, Fort Monmouth, into the potential of electroncutaneous stimulation for presenting certain classes of military information for Signal Corps' equipment systems. These studies, along with others, were completed over a period of a year and represent initial, introductory, and exploratory work. Currently, the work is being extended to more sophisticated signal systems.

Apparatus

For all of the studies, here reported, the apparatus consisted of: 1. an auditory signal generating apparatus, 2. an electrocutaneous signal generating apparatus, and 3. a visual signal generating apparatus.

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The auditory and cutaneous signals consisted of white noise generated by a Grason-Stadler model 455B generator, appropriately amplified and attenuated. The auditory signal was presented through a headset. The electrocutaneous signal was presented to the subjects by a silver plated copper foil electrical transducer which combined the active and indifferent electrodes. The electrical transducer was produced by using printed circuit techniques according to the general specification for a concentric transducer suggested by Faralla (1962). A provision was made for inserting a Simpson 260 meter in the transducer circuit so that subject's resistance could be monitored through the stimulating electrode before each electrocutaneous stimulus was delivered.

The visual signal apparatus was composed of a simulated cathode ray tube presentation. The apparatus allowed presentation of a simulated "blip" of known and variable intensity, with rapid rise and fall times, against an adequately uniform background of 0.8 foot lamberts.

For all stimuli, electro-mechanical stimulus programming and timing were employed. The response of the subjects, in terms of their reaction time to the various signals, was also automatically recorded. With the exception of the simulated radar scope, the headset, the electrocutaneous transducers, and the response pushbutton, all parts of the apparatus were housed in a room which was separated from the experimental room by an intervening sound proofed room.

Reaction to Auditory, Visual and Electrocutaneous Signals and Their Combinations

The first experimental work involved comparisons of reaction time and missed signals when auditory, visual, and electrocutaneous signals and their combinations were employed as stimuli. To this end, for each of seven subjects the 100% detection threshold for visual stimuli was first determined by the method of constant stimuli. Auditory and electrocutaneous signals of intensity subjectively equivalent to the 100% visual threshold were then obtained for each subject.

The experiment proper involved a vigilance task in which the effects of stimulus mode and stimulus duration were examined within a complete factorial design involving repeated measurements on the seven subjects. Portion of the watch in which the stimulus appeared was investigated within this design. The subjectively equally intense visual, auditory, electrocutaneous stimuli, and all possible combinations were presented to each subject at 0. 3 and 0. 1 second durations in a counterbalanced order. Each stimulus type was presented to each subject at each duration during a single 45 minute vigilance watch. Each watch was composed of three 15 minute segments, and within each segment three stimuli were presented at interstimulus intervals of 1, 5, and 9 minutes. The order of interstimulus intervals was distributed randomly within each segment.

The task of the subject was to respond by depressing the response push-button, as quickly as possible, when he sensed a signal.

If a subject missed a signal, the signal was repeated. A stimulus was considered to have been missed if the subject failed to respond within three seconds after signal presentation. If the subject failed to respond in this interval, the signal was repeated.

The response latency data were treated by analysis of variance to determine the effects of varying stimulus mode, stimulus duration, and interstimulus interval on latency of response. The variance analysis indicated that both stimulus mode and stimulus duration exerted a statistically significant effect. Interstimulus interval as well as the first and second order interactions were not statistically significant. Tukey gap tests were performed to identify the stimulus conditions responsible for the significant modality effect. The gap tests indicated that the responses to the visual signal alone were significantly slower than to any of the other stimuli, and that response latency to the auditory and the cutaneous signal conditions did not differ significantly. However, the combination of cutaneous stimuli with the visual and the auditory were significantly different from the other conditions.

Since the missed signal data were highly skewed, Friedman's technique, a nonparametric variance analytic technique, was employed to access these data. A significant modality effect on first signal detection was found. The results are shown graphically in Figure 1. The detected first signal results support the response latency data with combinations of signals being superior and with the visual signal being the poorest of the uni-modal stimulus types.

Suprathreshold Determinations

The first experiment suggested that for subjectively equivalent, near threshold intensity stimuli, when the subject was aware of the type of stimulus he was to receive, significant differences existed between the various modes of stimulus presentation employed. The questions remained open of whether or not these results hold when the subject is unaware of which stimulus mode or combination of modes he is to receive on a given trial, and when the intensity of stimuli are more nearly in a practical operational range, i.e. well above threshold intensity. Experiment II was designed to test these questions.

In experiment II, the same apparatus was employed as for the previous experiment. Only one stimulus duration was used (it will be remembered that no significant duration effect was obtained in the prior study 1). Threshold intensities were established for each subject in a manner similar to that employed in the first study and stimulus intensities set at twice the threshold intensity for each subject. The experiment was divided into six, thirty-six minute watches. Twelve stimuli appeared in each watch. The order of stimulus presentation for any watch was arranged in counterbalanced order so that each possible stimulus mode occurred twice, the last six stimuli being in the reverse order of the first six. Each watch began with a different stimulus mode and the interstimulus intervals employed (1, 3, and 5 minutes) were randomly dispersed throughout each watch. However, the same number of each interval appeared

in each watch. Each of five subjects started the experiment with a different watch and then continued through all six watches in serial order.

The mean latency results generally supported those of the first study and are presented in Figure 2. A non parametric analysis of variance indicated a statistically significant difference between ranks. Figure 2 suggests that, across subjects: (1) the combined stimuli were somewhat more effective than single stimulus presentations, (2) the visual stimulus, when compared with the other unimodal stimuli, generally evoked the longest response latencies, and (3) little, if any, difference in response latency was exhibited between the auditory and the electrocutaneous stimuli.

Analysis of the missed signal data by mode again yielded statistically significant results. These differences also seem to possess greater practical significance than the latency data. For example the least missed signal, the auditory-electrocutaneous, was detected 98% of the time; 59% of the visual signals were missed on their first presentation.

Task Sharing and Collateral Task Adequacy

Many military situations call for divided operator attention. For example, operation of a tank may call for guiding the tank and avoiding obstacles while simultaneously watching for the impact point of projectile. Or, controlling an aircraft's approach may call for monitoring a radar scope while simultaneously performing a number of mental coordinating or calculating processes.

The third experiment, completed with the collaboration of Mr. J. David Barcik, was designed to investigate performance proficiency in a divided attention situation. Empirical data were sought which would provide a comparison of the speed and accuracy of performing either a perceptual-motor or a cognitive task while simultaneously attending to a visual or an electrocutaneous display.

Eight male subjects were required, after practice, to monitor the visual display or to attend to a subjectively equivalent electrocutaneous signal while performing simple arithmetic computations or a simple perceptual-motor task. The visual and electrocutaneous signals consisted of one "dot," two "dots," or three "dots" either presented on the simulated radar scope or through the electrocutaneous transducer. The mental arithmetic problems consisted of the addition, subtraction, or both, of five numbers and indicating which one of five alternative answers was correct. The total number of problems attempted and total correct were counted and used in the subsequent analyses. The perceptual-motor task consisted of drawing a pencil line in a narrow space between two concentric circles without touching or crossing the limits of either circle. Two sets of concentric circles were used. One set was composed of circles of diameters 12 and 9 millimeters; the other was composed of circles of diameters 9 and 6 millimeters. In use, the subject alternated between the large and the small sets.

The significance of the differences between the number of attempted problems as well as the number of correct problems for both the cognitive and the perceptual motor tasks under the two signal mode monitoring conditions was tested by the "t" test, with correction for correlated populations. All differences were significant below the .01 level of confidence. The mean and standard deviation for each condition are presented in Table 1.

Table 1

Mean and Standard Deviation of Number of Attempted and Number of Correct Problems by Signal Mode

		Cognitive		Perceptual-Motor	
		Vis.	ECT	Vis.	ECT
Number Attempted	$\overline{X}$	38.6	48.5	142.0	166.0
	σ	10.3	9.2	26.9	39.0
Number Correct	$\overline{X}$	36.9	46.9	58.5	80.5
	σ	9.9	8.6	21.4	20.8

More striking is the fact that no electrocutaneous signals were missed, whereas 81 visual signals were missed. Error scores (wrong responses to a one, two, or three "dot" signal) followed the same trend as the missed signal data with more errors in response to the visual than to the electrocutaneous signals.

These results generally support the work of Hawkes, Alluisi, and Meigham (1963), who also found that performance proficiency on a number of tasks was not impaired in the presence of electrocutaneous stimulation, and of Glucksberg (1963), who found that tracking performance was not impaired under electrocutaneous stimulation, but was impaired under visual stimulation.

Psychophysiological (Emotional) Response to Electrocutaneous and Auditory Stimuli

The above three studies suggest that electrocutaneous signals may possess some merit as a technique for transferring information to the operator of a man-machine system. However, it may be conjectured that the subjective or emotional response to electrical stimulation will be such as to mitigate the usefulness of this type of signal. Accordingly, an experiment was designed to compare psychophysiological indicators of emotional reaction when "high" and "low" intensity electrocutaneous and subjectively equal "high" and "low" auditory stimuli are involved.

Three classes of indices were adopted as indicators of emotional reaction to the signals involved: (1) heart action, (2) skin resistance, and (3) respiratory system action. Each of these has been traditionally employed as a reflector of autonomic nervous system activity. If these measures consistently reflect greater emotional reaction to the electrocutaneous than to the auditory stimuli, then tangential questions involving the ultimate practicality of electrocutaneous information transmission may become opened.

The psychophysiological monitoring and recording was performed with the three channel Physiograph, a standard device manufactured by the E and M Instrument Company. Heart rate was sensed through a photoelectric pulse pickup taped to the subject's second finger. GSR was sensed through standard silver electrodes taped to the underside of the lower forearm, near the elbow. Respiratory function was sensed by an impedance pneumograph. The plates of the pneumograph were taped over the fifth rib of the ventral chest wall. The GSR preamplifier and the pneumograph were operated in the A.C. and direct coupled modes respectively, thus assuring steady baselines.

Subjectively equivalent "high" auditory and electrocutaneous signals and subjectively equivalent "low" auditory and electrocutaneous signals were established for each of three subjects, employing a standard psychophysical method. The standard weak electrocutaneous stimulus in these comparisons was set at a level that had been detected 100% of the time by all subjects during the intensity matching sessions of the first experiment here reported. The standard strong auditory stimulus was a 10.1 milliwatt white noise signal through the earphones. This was selected so as to be adversively intense to all subjects.

A 2 x 2 experimental design was employed. Four consecutive experimental sessions were administered in counterbalanced order to four subjects on each of two days, a practice day and an experimental day. The subjects were told which class of signal they would receive during a vigilance watch and

that they should respond to the signal by depressing the response pushbutton as rapidly as possible, for this "task is to fire an anti-missile missile..."

Pulse frequency was counted for each 10 second interval from the start to the finish of the record pertaining to each stimulus type and level and separately for the 10 seconds following each auditory or electrocutaneous stimulus presentation. Separate basal and post-stimulus means and standard deviations were than obtained for each subject. Analysis failed to support the contention that the weak or the strong electrocutaneous stimulus had any effect on heart rate that was different from the comparative auditory stimulus.

Frequency and standard deviation of GSR response, defined as any deviation from basal greater than 300 ohms/second were obtained for each subject in each condition separately for each 10 second period following each stimulus presentation and over the remainder of the record. GSR amplitude was measured by experimental condition at two second intervals separately for each 10 second period following each stimulus presentation and for the remaining part of the record. Finally the pure GSR range was obtained. These data similarly failed to demonstrate any differential effect that could be attributed to the two types of signals involved.

Basal breathing rate was defined as the number of inspiration-expiration cycles for the ten second interval preceding each stimulus. The post-stimulus rate was determined from the record of the five seconds following each stimulus. Respiration amplitude was defined as the maximum trace height above resting

level for each inspiration-expiration in the ten second period preceding a stimulus and the five second period following a stimulus. Both breathing rate and breathing amplitude showed increases in the post-stimulation period with little, if any, differential effect that may be attributed to signal type evident. However, the standard deviation for the strong signal appears to have been higher when the auditory signal was employed than when the electrocutaneous signal was employed.

The question may be raised of whether or not the experimental subjects did, in fact, attend to the experimental situation and attempt to respond by depressing the response pushbutton as rapidly as possible after they detected a signal. Analysis of the response latency indicated that: (1) mean latency decreased, as expected, as signal intensity increased, (2) response latencies to the signals were compatible with those found in other experiments of this series.

Affective Reaction to Electrocutaneous Stimulation

The previous experiment suggested support for the contention that, from the psychophysiological reaction point of view, little difference between the emotional reaction to subjectively equivalent electrocutaneous stimulation and auditory stimulation may be anticipated. However, it is possible that a subjectively negative affective response may be expected from electrocutaneous stimulation. The next study investigated the subjective affective tone of electrocutaneous stimuli through an adjectival check list.

The adjectival check list contained 29 adjectives. Thirteen pairs of these were selected to represent affective tones, which might be employed to describe an electrocutaneous signal in a bipolar manner, e.g., "variable" - "regular," "pleasant" - "painful." Three additional adjectives were added: "bright," "ticklish," and "disturbing."

The adjectival check list was administered twice to subjects, once at the end of the first session and again following the last session in each of the previous experiments.

The data indicated that the electrocutaneous stimuli used in the experiments were most often described as eliciting "moderately mild," "regular," "ticklish," "tingling" sensations. The single most adequate descriptive adjective was "tingling." The adjectives used least often to describe the electrocutaneous stimuli were "boring," "moving," " painful," "compressed," and "diffuse." Adjectives connoting a negative affective tone such as "strong," "painful," "burning," and "disturbing" were seldomly selected.

The Spearman rank correlation between the first and second administrations of the adjectival check list was .876, indicating acceptable stability of reaction within the time ranges involved.

Space was provided on the checklist for the subject to add additional adjectival descriptors, if he so desired. Additional adjectives listed were: "different (from any other sensation), relaxing (but not sleep inducing), scintillating, enjoyable, safe, warm, easy, light, pinprick, clear, distinct, confortable, needlelike, and prickly."

Our studies of electrocutaneous signal transmission are continuing and other studies, not here reported, have been completed. Our general conclusion at this point is that electrocutaneous signals possess considerable merit for cautionary-warning signal applications, particularly if this type of signaling system is coupled with an auditory signal.

References

Faralla, R. A. Guidelines to communications by electrical stimulation. Fort Monmouth: Memorandum Report, 1962.

Hawkes, G. R., Alluisi, E. A., and Meigham, T. W. Monitoring performance with varying levels of task demand. Human Factors Res. Lab., 1963.

Glucksberg, S. Rotary pursuit tracking with divided attention to cutaneous visual, and auditory signals. Human Eng. Lab., 1963, AMCCMS Code 5014.11.841.

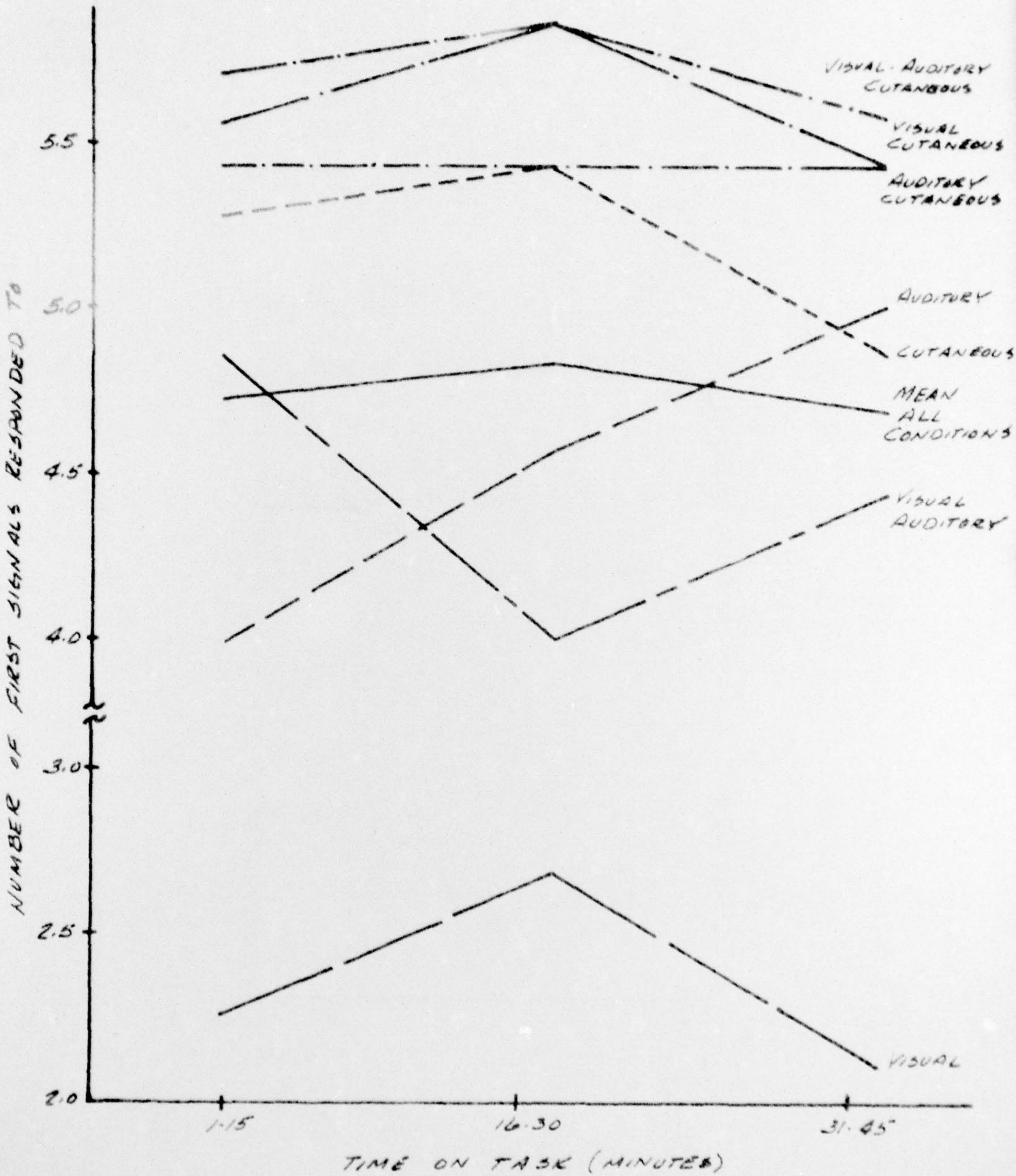

Figure 1 Number of first signals responded to in each condition as a function of time on task.

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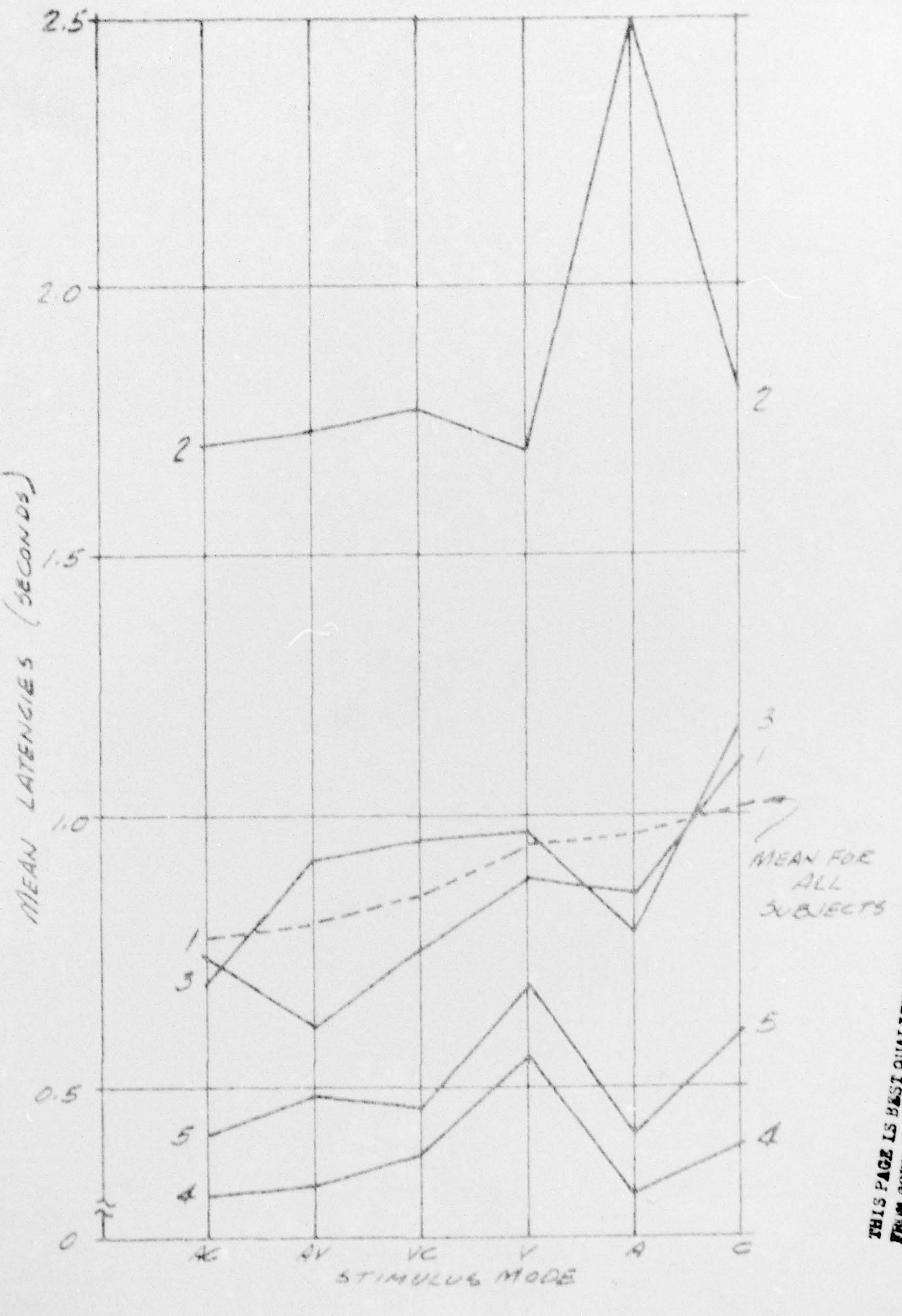

Figure 2. Mean response latencies by stimulus mode for each subject.

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